PERFORMANCE OF FORAGE CROPS ON A DRAINED SALINE SEEP

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ABSTRACT

The performance of six alfalfa cultivars and three grasses was evaluated on the basis of yield from field plots on an underdrained saline seep in southern Alberta. Yields were also evaluated as a function of mean annual and seasonal water-table depth. The study encompassed three cropping years, after an initial crop establishment year.

Treatment yields were normalized on an annual and a total cropping-year basis for the performance evaluation. Normalized annual yields of subplots were used to determine the relationship between crop yield and water-table depth. Results showed that the best performing alfalfa cultivar was Trek while Beaver was second best. Yields of Trek and Beaver were significantly different at $P < 0.05$ from that of Drylander. The optimum mean annual water-table depth for maximum yield of alfalfa cultivars ranged between 1.55 and 1.68 m. Of the grasses tested, tall wheatgrass (TWG) greatly outperformed Altai wild rye and slender wheatgrass (significant at $P < 0.05$). An optimum mean annual water-table depth at about 1.3 m or greater equated with maximum yield of the grasses.

INTRODUCTION

A large area of agricultural land in the Canadian prairies is affected by soil salinity. Estimates are in excess of 2 million ha with associated losses in crop production estimated to exceed 25 million dollars per annum (P.F.R.A., 1983). Part of this land was saline prior to settlement (natural salinity) but the greater part has become salinized in the recent past (Sommerfeldt et al., 1984). Side-hill saline seeps are prominent examples of recent or secondary salinity.

Saline seeps are characterized by excess water and high soluble salt contents. Excess water is not necessarily synonymous with waterlogged conditions. For most agricultural crops, excess water may already occur when part of the root zone is wetted to such a degree that the oxygen supply for root respiration is deficient. The depth to which the water table needs to be lowered for optimum crop production has been fairly well established for most crops, provided the excessive wetness is due to non-saline water (Wesseling, 1974). Little information is available on the effect of drainage of saline land on crop production. Oosterbaan (1981) reported that water-table depths at harvest time, when greater than 0.6 m below the land surface, did not influence the grain yield of irrigated sorghum. He found that the relationship between yield and water-table depth was not linear. Such results may not be applicable to dryland saline seeps as leaching of salts is solely dependent on natural precipitation. This paper reports the performance of dryland forage crops grown on an underdrained saline seep and evaluates the relationship between crop yield and water-table depth.

MATERIALS AND METHODS

Site and Soil Characteristics

The study site is located 25 km northwest of Lethbridge, Alberta, about 0.5 km south of the Town of Nobleford. It is situated on a 7% south-facing slope of a 425-ha closed watershed. The area was settled in 1904. Agricultural land management which consisted of summerfallow in alternate years for water conservation purposes had been the common practice in this area. Indications of a rise in groundwater level presented themselves in about 1950 when areas of lush vegetation appeared on sideslopes. Sideslope saline seeps were well established by 1960. The seepage area of the study site was fed by groundwater having an electrical conductivity of about 10 dS/m.

Dark Brown Chernozemic soils of the Lethbridge map unit are the dominant soils of the basin (Alberta Instit. Pedology, 1977). Significant inclusions of Whitney and Pulteney soils in the Lethbridge map unit occur in the northern one-third of the basin. Lethbridge soils have developed in coarse- to fine-loamy fluvial or lacustrine material, Whitney soils in a blanket and Pulteney soils in a veneer of this material over fine-loamy morainal material. At the experimental site, the soil material is that of the Lethbridge map unit.

<u>Experimental Layout</u>

Subsurface plastic drains were installed in the winter of 1977 to intercept saline groundwater coming into the seepage area (Fig. 1). The main line consisted of 150-mm and the interceptors or laterals of 100-mm diam. perforated plastic tubing (Oosterveld and Sommerfeldt, 1979). Three interceptor drains were installed perpendicular to the land slope and at a minimum depth of 160 cm and a maximum depth of 200 cm using trenching equipment. A nylon filter was used on the furthest upslope lateral to prevent sediment from entering the drain.

The western half of the drained area was fenced off in 1982 to conduct a cropping experiment. Groundwater observation wells were installed at specific distances perpendicular to the drain laterals along the east and west fence-lines. The midpoint wells were monitored weekly and all others monthly. Eleven 16x3-m plots were laid out across each lateral (Fig. 2). Seedbed preparation included incorporation of 45 kg/ha P_2O_5 and 60 kg/ha K at time of seeding on all plots, based on soil-test results. Six alfalfa cultivars, three grasses, sainfoin (all at 10 lbs/acre), and safflower (60 lbs/acre) were sown with an 18 run, double disk press drill according to a completely randomized block design. The growing seasons of 1983 and 1984 were marked by total crop failures.

Crop establishment succeeded in 1985 partly as a result of manual and chemical weed control (Embutox-E). All perennial crops needed underseeding in the spring of 1986. Also in 1986, an unregistered flax selection, STS, was sown in place of sainfoin. In subsequent years, the flax and safflower plots were rotated on an annual basis.

Yield Measurement and Statistical Analyses

Yield-measurement plots were established at 1 m and 7 m upslope and at 7 m downslope from each drainline for all plots in the experiment. A 0.25 m^2 frame was used to harvest the hay samples at these locations. The total wet weight of the samples was recorded before and after removal of foreign plant material. The cleaned samples were oven-dried at 80°C, weighed, and ground with a Wiley mill. Annual yields were totals of two or three harvests, depending on crop and year. All yields are reported on a dry weight basis.

Analysis of Variance (ANOVA) was conducted on the annual and the total yields of all cropping years and the significance was evaluated with Tukey's studentized range test.

RESULTS AND DISCUSSION

Crop Performance

Hay yields from three cropping years, after an initial crop establishment year, are shown in Tables 1 and 2. The annual data represent the total yield from two cuts, except for the 1987 alfalfa-hay yields which represent the total of three cuts.

The 1986 alfalfa yields were about half that of the following years (Table 1). This was attributed to poor stand establishment relating to seed-placement method which necessitated underseeding of all forage plots in the spring of 1986. Yields generally improved with age over the three cropping years. An exception was the yield of cultivar Trek, which was lower in 1988 than in 1987. As Trek was selected for irrigated conditions, the drop in yield appeared related to the more intense drought in 1988 compared to previous years. Highest yields in 1986 and 1987 were provided by Trek while Beaver was the best performer in 1988.

The 1986 yields of the alfalfa cultivars were not significantly different at $P > 0.05$. In 1987 and 1988, the yields of Trek and Beaver were significantly different from that of Drylander. Similarly, Trek and Beaver yields for all crop years were significantly different ($P < 0.05$) from that of Drylander (Table 3). Ranking the cultivars in terms of percent yield relative to Beaver showed Trek as best performer in the first two years and second best in the last cropping year. Beaver improved from fourth place in 1986 to best performer in 1988. In each year and overall, the three best performers consisted of one irrigated and two dual-purpose cultivars. The poor performance of Drylander over the course of the study and the variable performance of Roamer, Kane, and Heinrichs was attributed partly to differences in the regrowth capability of the cultivars. According to the Alberta Agriculture (1987), Drylander, Roamer, and Kane have slower recovery after cutting than Heinrichs which, in turn, has slower recovery than Beaver and Trek.

The yields of the grasses in 1986 were also about half that in the following years (Table 2), owing probably to seed-placement method. The yield of TWG was significantly different from that of SWG and Altai wild rye in 1987 and 1988 and on an overall basis (Table 3). Yield and ranking of SWG tended to decrease while those of Altai increased with age over the three cropping years. The perceived gradual improvement in the performance of Altai was ascribed to its known slowness in plant establishment. The decreasing performance of SWG with age was attributed to the short lifespan of this native bunch grass (Alberta Agriculture, 1987).

Crop Yield - Groundwater Level Relationships

The variations in mean annual water-table depth did not influence the Trek alfalfa yield when the water table was deeper than 1.6 m below the land surface (Fig. 3). However, yields decreased when the water table was at less than 1.6 m depth. The relationship between groundwater level and Trek yield was not linear, but could be approximated by an upward sloping line for water-table depths between 0-1.6 m and a horizontal line for depths greater than 1.6 m (Oosterbaan, 1981). Acceptance of the breakpoint at a water-table depth of 1.6 m was supported by the finding of Benz et al. (1983) that the optimum water-table depth for maximum yield of irrigated Vernal alfalfa was 1.5 m. Hence, this line was taken to represent the maximum Trek yield in relation to mean annual water-table depths. The half-width of the area enclosed by the line and the x-axis was taken to represent the average yield obtainable. Application of this method of analysis to the TWG data showed that the breakpoint for optimum water-table depth occurred at 1.3 m (Fig. 4).

Analysis of all treatments by this method showed that the optimum water-table depth for alfalfa cultivars ranged between 1.56 and 1.68 m (Table 4). Maximum yield at optimum water-table depth ranged from 7.2 to 11.1 t/ha, and average yields from 3.6 to 5.5 t/ha. Kane had the lowest optimum water-table depth and highest maximum yield. This analysis suggested that the order of the three best performers, as determined by ANOVA of overall yield (Table 3), may invert to Kane>Beaver>Trek. In the case of the grasses, the average optimum water-table depth was approximately 1.3 m (Table 4). Maximum yield for TWG at optimum water-table depth was 11.8 t/ha. The optimum water-table depth for Altai was not clearly indicated by the analysis. In view of previously identified limitations to Altai establishment, no maximum or average yield was listed. For reasons indicated previously, the maximum yield of SWG would be expected to be higher than listed if yields had been taken in the year of crop establishment.

The influence of water-table depth on crop yield was also evaluated using the mean groundwater level during the growing season (Fig. 5) and that during the previous off-season (Fig. 6). The approximations of the relationship between yield and these water-table depths were deemed inferior to those obtained with mean annual water-table depths. This reduced the urgency to evaluate the dynamic criterion of SOW_x (= number of days times height of water table above a level, x, below land surface during the winter period), which has been found to give a more precise relationship between yield and water-table depth in rainfed, non-saline areas than the use of the static criterion of mean annual water-table depth (Feddes, 1988).

SUMMARY AND CONCLUSIONS

The performance of alfalfa cultivars and grasses was evaluated on the basis of yield from field plots on an underdrained, side-hill, saline seep in fine-loamy Lethbridge soil near Nobleford, Alberta. Yields were also evaluated in relation to mean annual and seasonal depth to the water table. Yields were not measured in the first year of the experiment in order to ensure satisfactory crop establishment.

In two out of three cropping years as well as on an overall bases, the best performing alfalfa cultivar was Trek, a cultivar recommended for irrigated use. Two dual-purpose cultivars, Beaver and Kane, were the next best overall performers. Yields of Trek and Beaver in the last two cropping years and in total were significantly different ($P < 0.05$) from that of Drylander. For the grasses, TWG greatly outperformed Altai and SWG in all three cropping years with its yields being significantly different from those of Altai and SWG at $P < 0.05$.

The relationship between total annual crop yield and either annual or seasonal water-table depth showed a general increase in yield with increase in depth of shallow water tables but at deeper water tables yield remained constant. This non-linear relationship was approximated by two straight lines: an upward-sloping one in the range of shallow water tables and a horizontal line for deeper groundwater levels. The point at which the two lines met (breakpoint) was taken to represent the optimum water-table depth for maximum crop yield. Maximum yields occurred at mean annual water-table depths equal to or greater than 1.55 to 1.68 m for the alfalfa cultivars and 1.20 to 1.40 m for the grasses.

The results obtained indicate that the return on investments for cropping a saline area is highly dependent on crop selection and on control of a shallow water table.

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Table 1. Dry matter yield and relative ranking of the annual alfalfa crops for the cropping years

Year	Cultivar	Mean yield (t/ha)	% Yield relative to Beaver	Ranking
1986	Beaver	2.2 a	100	4
	Roamer	2.4 a	110	2
	Trek	2.5 a	114	1
	Kane	2.4 a	109	3
	Drylander	1.0 a	45	6
	Heinrichs	1.1 a	50	5
1987	Beaver	5.8 a	100	2
	Roamer	3.1 ab	53	5
	Trek	6.8 a	117	1
	Kane	4.6 ab	79	3
	Drylander	1.1 b	19	6
	Heinrichs	3.2 ab	55	4
1988	Beaver	6.4 a	100	1
	Roamer	4.7 ab	73	3
	Trek	5.7 a	89	2
	Kane	4.5 ab	70	4
	Drylander	2.5 b	39	6
	Heinrichs	4.4 ab	69	5

Treatment means followed by the same letter are not significantly different ($P > 0.05$).

Table 2. Dry matter yield and relative ranking of the annual grass crops for the cropping years

Year	Grass	Mean yield (t/ha)	% yield relative to T.W.G.	Ranking
1986	TWG	3.3 a	100	1
	Altai	0.7 a	21	3
	SWG	0.8 a	24	2
1987	TWG	6.2 a	100	1
	Altai	1.2 b	19	2
	SWG	0.0 b	0	3
1988	TWG	6.5 a	100	1
	Altai	1.5 b	19	2
	SWG	0.3 b	5	3

TWG - Tall wheatgrass; SWG - Slender wheatgrass.

Treatment means followed by the same letter are not significantly different ($P > 0.05$).

Table 3. ANOVA and Tukey's test for significance of total yield of dry matter from the forage crops

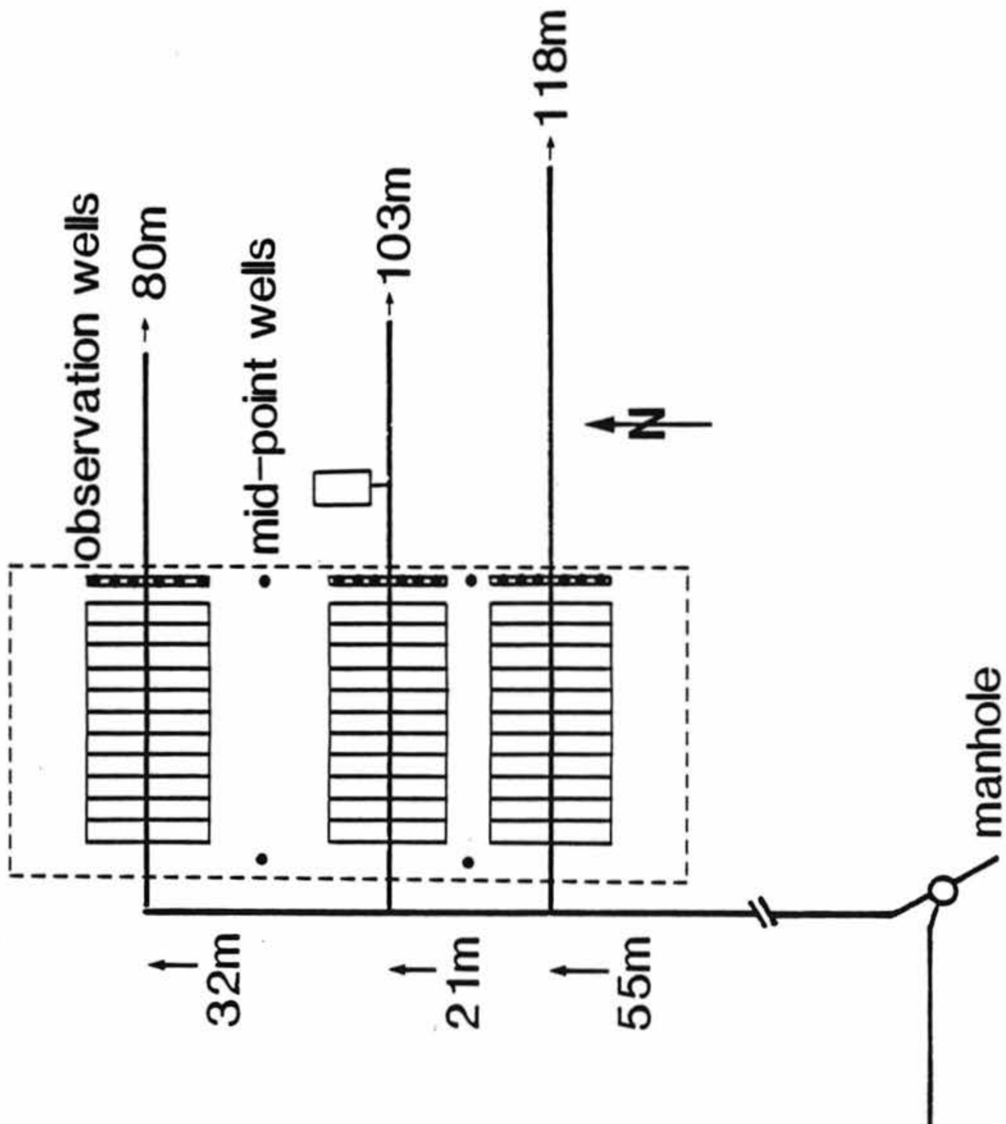
Alfalfa	Mean yield (t/ha)	Grass	Mean yield (t/ha)
Beaver	4.80 b	TWG	5.33 b
Roamer	3.40 ab	Altai	1.13 a
Trek	5.00 b	SWG	0.37 a
Kane	3.83 ab		
Drylander	1.53 a		
Heinrichs	2.90 ab		

Table 4. Optimum water-table depth and mean yield of alfalfa cultivar and grasses grown on a dryland saline seep

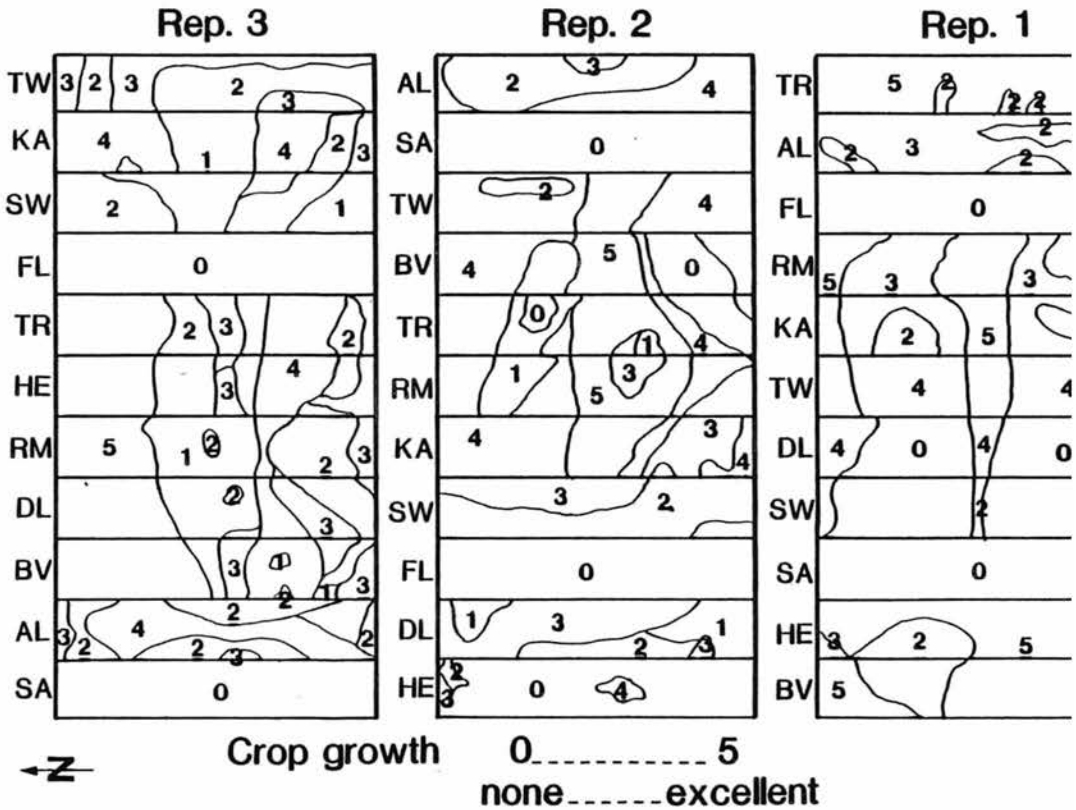
	Optimum water-table depth (m)	Maximum yield (t/ha)	Average yield (t/ha)
Alfalfa			
Trek	1.60	9.6	4.8
Beaver	1.60	10.3	5.1
Kane	1.56	11.1	5.5
Roamer	1.68	7.9	3.9
Heinrichs	1.67	8.8	4.4
Drylander	1.67	7.2	3.6
Grasses			
TWG*	1.30	11.8	5.9
Altai	1.20		
SWG	1.40	1.7	0.8

*TWG - Tall wheatgrass; SWG - Slender wheatgrass.

LIST OF FIGURES



observation wells
mid-point wells
80m
103m
118m
32m
21m
55m
N
manhole


Rep. 3
Rep. 2
Rep. 1
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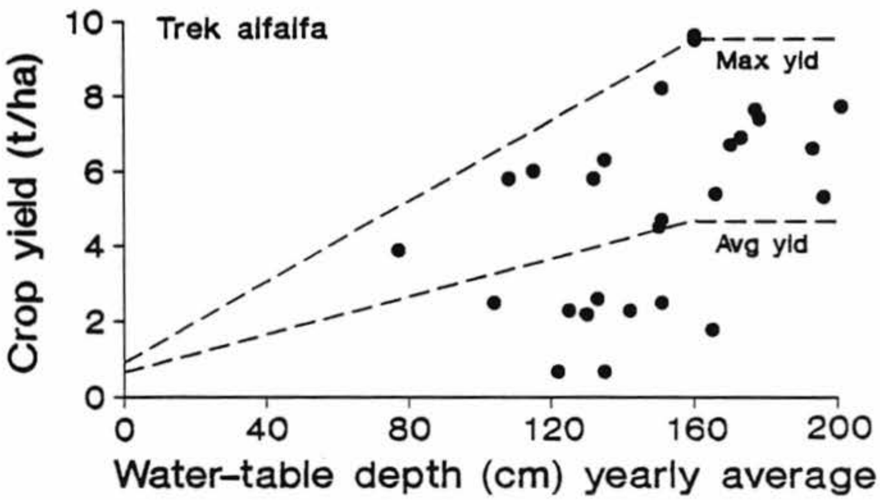
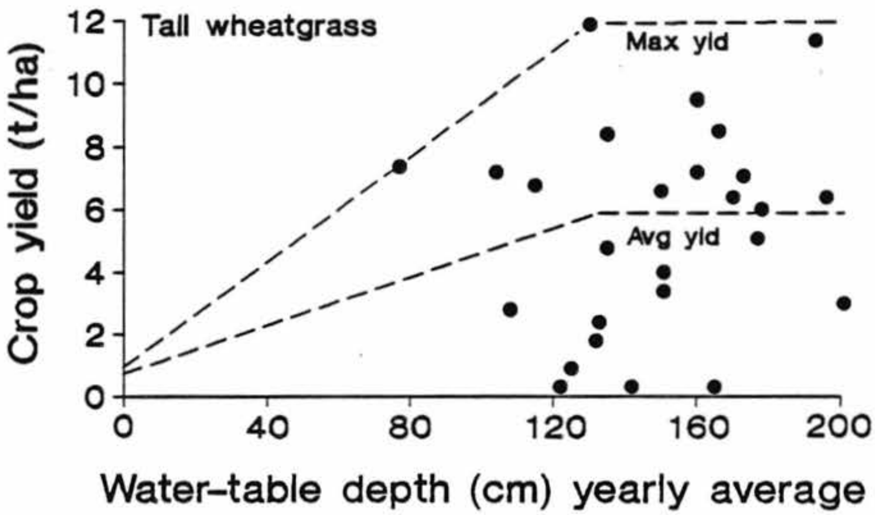
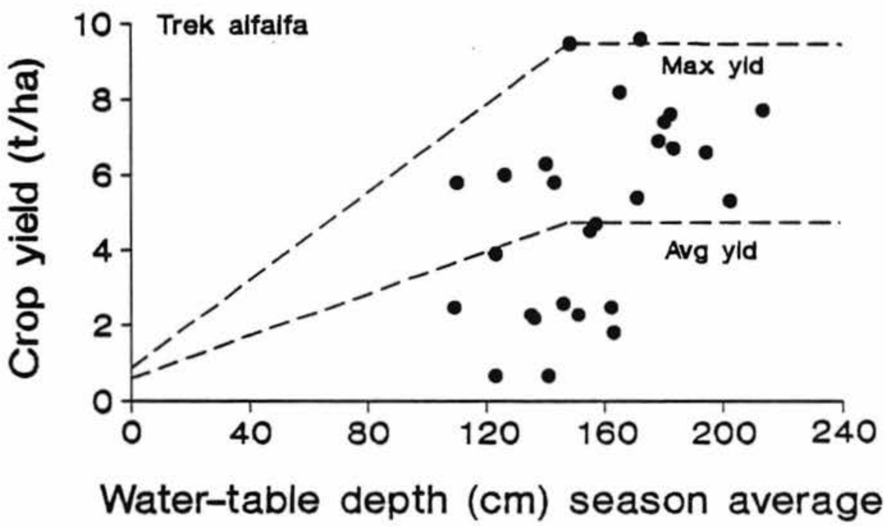
AL SA TW BV TR RM KA SW FL DL HE
TR AL FL RM KA TW DL SW SA HE BV
N
Crop growth 0 5
none excellent

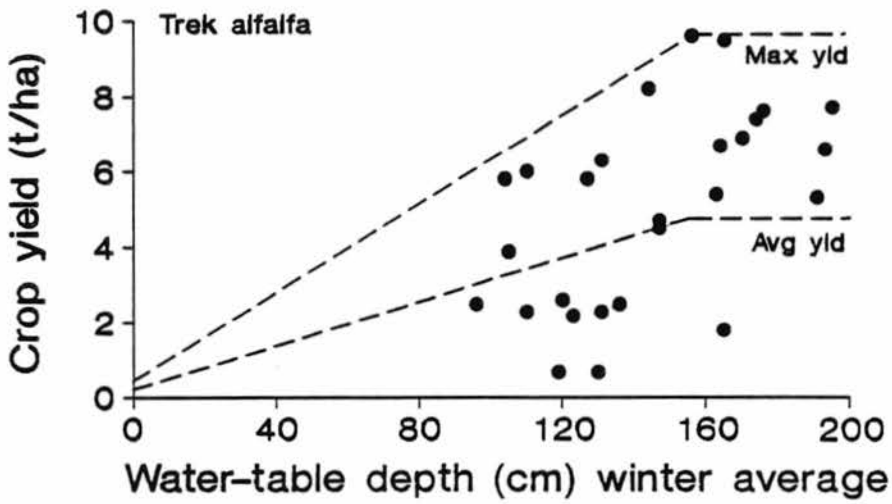


Trek alfalfa
Max yld
Avg yld
Crop yield (t/ha)
0
2
4
6
8
10
0
40
80
120
160
200
Water-table depth (cm) yearly average


Tall wheatgrass
Max yld
Avg yld
Crop yield (t/ha)
Water-table depth (cm) yearly average
0
2
4
6
8
10
12
0
40
80
120
160
200



Trek alfalfa
Max yld
Avg yld
Crop yield (t/ha)
0
2
4
6
8
10
0
40
80
120
160
200
240
Water-table depth (cm) season average


Trek alfalfa
Max yld
Avg yld
Crop yield (t/ha)
Water-table depth (cm) winter average
0
2
4
6
8
10
0
40
80
120
160
200